CSTDM09 – California Statewide Travel Demand Model

Model Development

Long Distance Commercial Vehicle Model

Final System Documentation: Technical Note

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1. Introduction

California Statewide Travel Demand Model (CSTDM09) has defined two separate models to be applied to forecast commercial vehicle travel generated by California business on a typical weekday in the fall.

The Short Distance Commercial Vehicle Model will apply for all trips made up to 50 miles from the home business establishment. The Long Distance Commercial Vehicle Model (LDCVM) will forecast vehicle movements greater than 50 miles. This distance classification is based on the observed spacing of depots for major delivery companies such as UPS, where vehicles and drivers are based at a home location and conform to a normal daily schedule and driver hours of operation requirements.

This technical note describes the Long Distance Commercial Vehicle Model (SDCVM) component of the CSTDM09. Section 2 gives an overview of the model. Section 3 details the factors used to convert CALSIM (PECAS) model output to truck flows by weekday time period. Section 4 gives details of the calibration of the model to observed Freight Analysis Framework (FAF) data for 2002. Section 5 describes how the model is applied in the overall CSTDM09 context.

2. Long Distance Commercial Vehicle Model Overview

The development of the LDCVM builds directly off the work being done at ULTRANS for the California Department of Transportation (Caltrans), to develop a computer-based model of the California spatial economic system using the CALSIM (PECAS) modeling framework. A base year 2000 PECAS model is being developed – the same base year being used for the state-wide travel model. Output from this PECAS model is being used to create an initial year 2000 weekday long distance commercial vehicle TAZ to TAZ trip table. Growth factors based on forecast changes in TAZ demographics are then applied to this base commercial vehicle trip table for future year scenarios.

It is important to note that:

- this approach is not dependent upon the availability of future year PECAS model outputs. The derivation of the model uses the base year 2000 PECAS model output as input, but application for future year scenarios is carried out using the resulting year 2000 commercial vehicle trip table and scaling factors. This means that the travel model can immediately be applied to future year scenarios.
- The PECAS model produces truck flows for all zone to zone pairs, for all distance ranges. Only those for origin-destinations > 50 miles are applied in the CSTDM09.

In the longer term it is expected that future year PECAS model run output will be available directly to inform and enhance the estimation of long distance commercial vehicle flows.

A full description of the PECAS model is given in the documentation of the California PECAS project. A brief overview is given below.

PECAS is a generalized approach for simulating spatial economic systems. It is designed to provide a simulation of the land use component of land use transport interactive modeling systems.

PECAS stands for Production, Exchange, and Consumption Allocation System. Overall, it uses an aggregate, equilibrium structure with separate flows of exchanges (including goods, services, labor and space) going from production to consumption based on variable technical coefficients and market clearing with exchange prices.

It provides an integrated representation of spatially distinct markets for the full range of exchanges, with the transport system and the development of space represented in more detail with specific treatments.

PECAS includes two basic modules that are linked together with travel models and aggregate economic forecasts to provide a representation of the complete spatial economic system.

Activity Allocation module (AA module): It represents how activities locate within the space provided by developers and how these activities interact with each other at a given point in time. Flows of exchanges from production to exchange zones and from exchange zones to consumption are allocated using nested logit models according to exchange prices and transport generalized costs (expressed as transport utilities with negative signs). These flows are converted to transport demands that are loaded to transport networks in order to determine congested travel utilities. Exchange prices determined for space inform the calculation of changes in space thereby simulating developer actions.

Space Development module (SD module): It represents the actions of developers in the provision of different types of developed space where activities can locate, including the new development, demolition and re-development that occurs from one point in time to the next. This developed space is typically floor space of various types. Developer actions are represented at the level of individual land parcels or grid cells using a micro-simulation treatment.

This linked system works through time in a series of discrete, fixed steps from one point in time to the next, with the AA module running at each point in time and the SD module considering the period from each point in time to the next. The system is run for each year being simulated, with the travel utilities and changes in space for one year influencing the flows of exchanges in the next year, as shown in Figure 1.
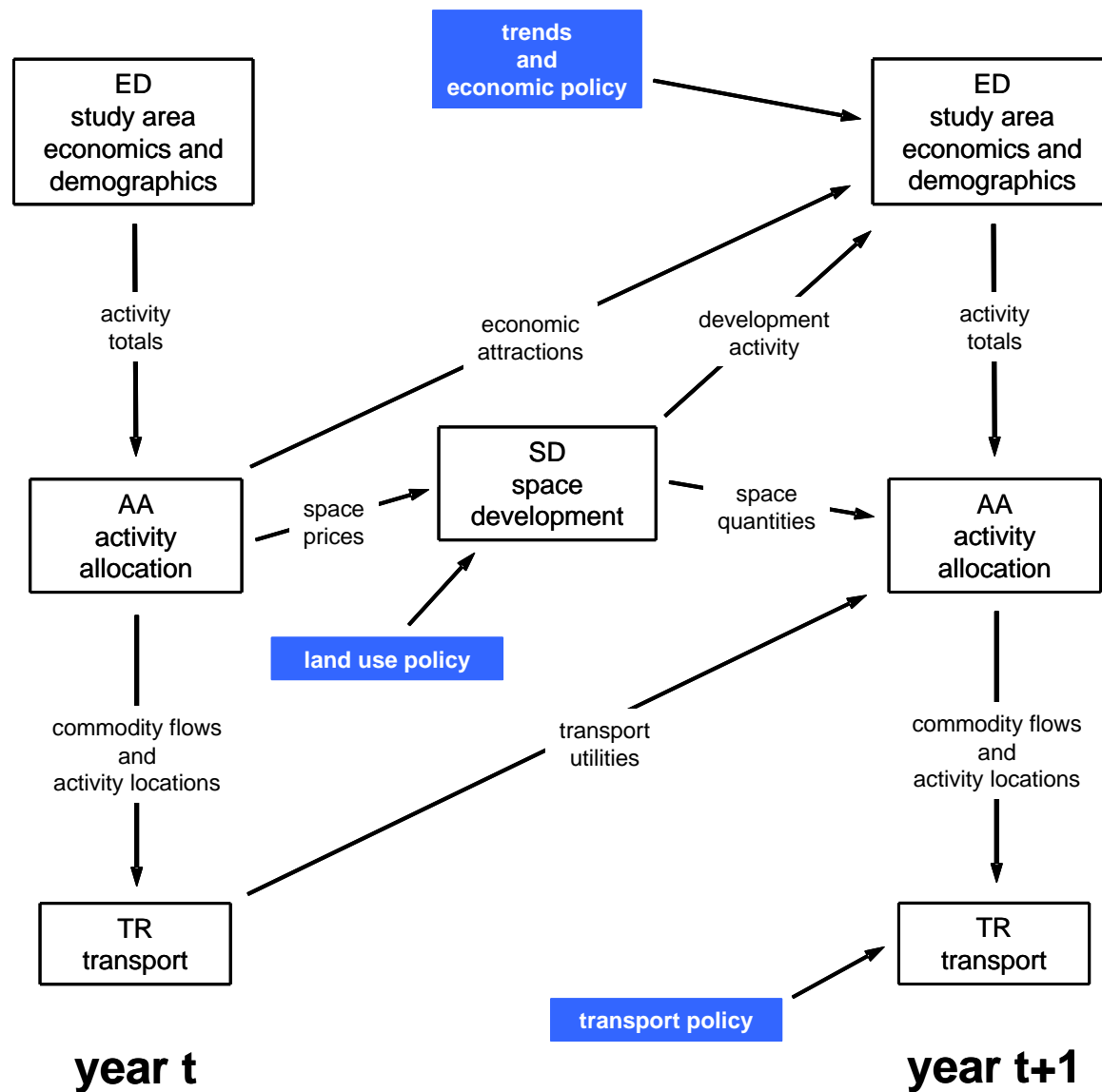
Figure 1: PECAS Modules and Information Flows Simulating Temporal Dynamics

The LDCVM application directly uses only the base year t (year 2000) output.

3. Conversion of Year 2000 PECAS Commodity Flows to Weekday Truck Flows

The California PECAS AA module is an aggregate representation applied at a "land use zone" (LUZ) level of geography. There are 524 LUZs in the California model. The 5,191 travel model TAZ system nests within these LUZs.

Activities are located in LUZs. Activities produce commodities and then transport and sell these commodities; they also consume commodities after buying them and transporting them. There are different types of activities, including industrial sectors, government and households.   The California PECAS model defines 59 output commodities (excluding labor and space categories) e.g. manufacturing textiles output. Activity quantities are usually measured in annual dollars.

The AA module allocates the study-area wide quantity of each activity among the LUZs as part of its allocation process. Commodities flow at specific rates from where they are produced to where they are exchanged (from seller to buyer), and then from where they are exchanged to where they are consumed. The movement of these flows of commodities from where they are produced to where they are consumed is the economic basis for travel and transport in the modeling system. The travel conditions – the distances, costs, times and associated disutilities by mode – for the movement of these commodities influence the interactions among activities and the attractiveness of locations for activities.

The AA module allocates the flows of commodities from production location LUZ to exchange location LUZ and from exchange location LUZ to consumption location LUZ, and finds the corresponding set of prices at the exchange location LUZ that clears all markets, as part of its allocation process. These LUZ to LUZ flows are also disaggregated into TAZ to TAZ level flows for use in the travel models.

Not all the producing activities in the California PECAS model generate significant goods movements, and resulting commercial vehicle movements for use in the travel model. Table 1 gives the 11 coomodities primarily generating goods movement:

Table 1: California PECAS Model Producing Activities for Goods Movement

PECAS Commodity
Agriculture Animals Output
Agriculture Plants Output
Agriculture Forestry and Fishing Output
Mining and Extraction Output
Manufacturing Food Output
Manufacturing Textiles Output
Manufacturing Wood Products Printing Furniture Misc Output
Manufacturing Petro Paper Chemicals Plastic Rubber Glass Cement Output
Manufacturing Metal Steel Machinery Output
Fuels
Scrap

The PECAS model outputs TAZ to TAZ level commodity flows for each of the above activities, in units of annual $ flows.

Freight Analysis Framework (FAF) data for 2002 is a primary source of factors to convert PECAS annual $ flows to truck flows. FAF is built and maintained by the Federal Highway Administration (FHWA). FAF consists of a set of models that are based primarily on survey data and statistical approaches to estimate freight flows at a significant level of detail.

The 2002 FAF consists of three four-dimensional matrices (for tons, ton miles, and value) in which the four dimensions are origin, destination, commodity, and mode.

Commodities are defined at the 2-digit SCTG (Standard Classification of Transported Goods) level. Modes are defined as in the 2002 Commodity Flow Survey. 11 separate modes are defined, including "truck".

From the FAF2 data it is possible to derive appropriate California factors for annual truck tons generated per million $ of annual commodity flow. Table 2 gives these factors for the PECAS production activities. The following approaches were used to obtain these factors:

- IMPLAN year 2000 Annual "Make $" data for California, broken down into 528 categories, was used to provide weightings to convert FAF2 data for SCTG commodity categories to PECAS categories;
- The use of a truck ton rate per million $ of total commodity flow explicitly takes into account the truck mode share for each commodity flow.

Table 2: Truck Tons Per Million $ of Commodity Flow for California PECAS

PECAS Commodity	Truck Tons per Million $
Agriculture Animals Output	923
Agriculture Plants Output	2,253
Agriculture Forestry and Fishing Output	2,889
Mining and Extraction Output	32,294
Manufacturing Food Output	1,226
Manufacturing Textiles Output	73
Manufacturing Wood Products Printing Furniture Misc Output	585
Manufacturing Petro Paper Chemicals Plastic Rubber Glass Cement Output	2,424
Manufacturing Metal Steel Machinery Output	192
Fuels	1,987
Scrap	10.301

Some differences exist between the annual dollar make quantities for each commodity reported in IMPLAN and used in the PECAS model, with the annual dollar quantities reported in the FAF data. Table 3 gives the conversion factors required to adjust truck flows derived from PECAS annual dollar commodity flow quantities with commodity flows reported in the FAF data.

Table 3: Adjustment Factors : PECAS Commodities $ to FAF $

PECAS Commodity	Adjustment Factor
Agriculture Animals Output	2.581
Agriculture Plants Output	2.590
Agriculture Forestry and Fishing Output	0.248
Mining and Extraction Output	0.370
Manufacturing Food Output	1.055
Manufacturing Textiles Output	0.856
Manufacturing Wood Products Printing Furniture Misc Output	1.261
Manufacturing Petro Paper Chemicals Plastic Rubber Glass Cement Output	0.781
Manufacturing Metal Steel Machinery Output	0.873
Fuels	1.019
Scrap	0.463

Washington State data from the Cross-Cascades Corridor Freight O/D Study can be used to derive average truck loads in tons, for each PECAS Commodity type, given in Table 4. (The original data was defined in STCC (Standard Transportation Commodity Codes) commodity categories. IMPLAN data was used to apply appropriate weights to convert the STCC data to PECAS commodity categories).

Table 4: Average Truck Loads in Tons for California PECAS Commodities

PECAS Commodity	Tons per Truck
Agriculture Animals Output	13.59
Agriculture Plants Output	21.05
Agriculture Forestry and Fishing Output	19.84
Mining and Extraction Output	14.65
Manufacturing Food Output	14.97
Manufacturing Textiles Output	9.94
Manufacturing Wood Products Printing Furniture Misc Output	15.48
Manufacturing Petro Paper Chemicals Plastic Rubber Glass Cement Output	15.26
Manufacturing Metal Steel Machinery Output	15.38
Fuels	21.40
Scrap	15.60

The Highway Capacity Manual suggests that annual truck flows can be converted to typical weekday by using a factor of 300 weekdays per year. This factor is used in a number of other freight modeling projects including the 2002 study "Freight Impacts on Ohio's Roadway System" and the 2005 New Jersey "Northerly Crossings Corridor Congestion Mitigation Study". A factor of 300 is therefore used in the CSTDM09 to convert annual truck flows to weekday truck flows.

The truck ton per million $ of commodity flow rates given in Table 2 are combined with the adjustment factors in table 3, and the average truck load rates in Table 4, and the 300 weekday to annual truck flow factor, to give typical weekday truck flows per million $ of annual commodity flows, as given in Table 5.

Table 5: Weekday Truck Flows per Million $ Flow for PECAS Commodities

PECAS Commodity	Weekday Trucks per Million $
Agriculture Animals Output	0.5842739
Agriculture Plants Output	0.9240546
Agriculture Forestry and Fishing Output	0.1201988
Mining and Extraction Output	2.7188427
Manufacturing Food Output	0.2880447
Manufacturing Textiles Output	0.0211093
Manufacturing Wood Products Printing Furniture Misc Output	0.1587953
Manufacturing Petro Paper Chemicals Plastic Rubber Glass Cement Output	0.4133390
Manufacturing Metal Steel Machinery Output	0.0364065
Fuels	0.3153964
Scrap	1.0185988

The daily truck flow matrices, obtained from the PECAS model output & applying the factors from Table 5, are assigned to time periods based on analysis of time of day distribution of observed truck flows at key inter-regional locations in California. Data from all the screen-line sites in California for heavy truck movements by time of day were averaged to give these time period distributions. Table 6 gives long distance truck volume time of day factors.

Table 6: Time of Day Factors for Weekday Long Distance Truck Flows

Time Period	Proportion of Weekday
Off Peak (3AM to 6AM plus 7PM to 3AM)	0.306
AM Peak (6AM to 10AM)	0.199
Midday (10AM to 3PM)	0.302
PM Peak (3PM to 7PM)	0.193

4. Calibration to Observed FAF Flows

Freight Analysis Framework (FAF) data for 2002 is the primary source of calibration targets for the long distance commercial vehicle model. The 2002 FAF consists of three four-dimensional matrices (for tons, ton miles, and value) in which the four dimensions are origin, destination, commodity, and mode.

Origins and destinations consist of 114 regions as defined and used in the 2002 Commodity Flow Survey (CFS). California is divided into 5 regions (Los Angeles (including the Inland Empire of Riverside and San Bernardino counties); San Francisco; San Diego; Sacramento; Rest), as shown below - plus 17 international gateways (see Figure 2).
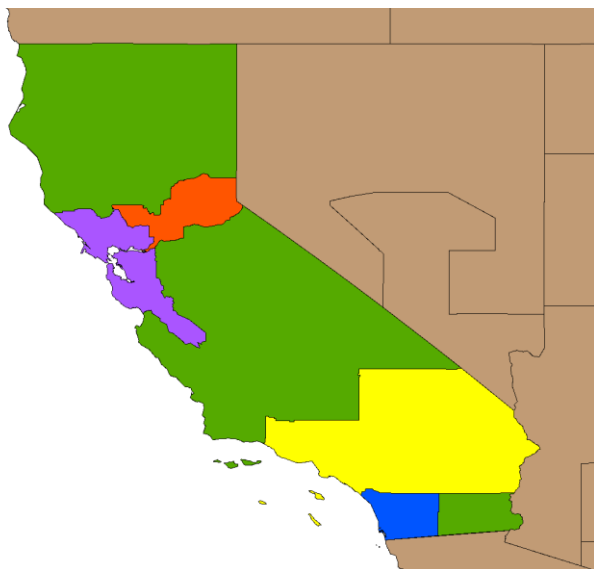
Figure 2: Commodity Flow Survey Districts

Table 7 gives 2002 FAF data for "internal California" annual truck tons flows by commodity type between the 5 FAF California regions (including intra-region flows).

Table 7: 2002 Annual Truck-Ton Commodity Flows between California Regions

Commodity	STCG	CA Los A	CA rem	CA Sacra	CA San D	CA San J	Total
				Destination			
Alcoholic beverages	8	4,633,860	1,846,220	836,590	492,270	1,660,590	9,469,530
Animal feed	4	8,743,550	14,604,870	4,877,610	3,407,730	4,213,870	35,847,630
Articles-base metal	35	6,486,010	1,281,100	1,175,270	1,016,230	2,937,670	12,896,280
Base metals	32	4,767,550	1,159,290	1,048,810	827,150	1,774,690	9,577,490
Basic chemicals	20	3,919,920	4,648,260	600,520	128,810	1,051,990	10,349,500
Building stone	10	378,120	86,790	57,310	69,580	231,910	823,710
Cereal grains	2	9,398,480	5,472,770	917,750	1,610,340	4,108,830	21,508,170
Chemical prods.	23	1,916,710	2,131,070	796,230	228,140	870,830	5,942,980
Coal	15	33,660	6,730	4,820	5,640	18,610	69,460
Coal-n.e.c.	19	19,782,850	8,213,800	4,529,770	6,287,690	9,664,570	48,478,680
Crude petroleum	16	439,920	67,900	230	340	312,730	821,120
Electronics	35	2,800,620	265,860	172,840	37,590	515,350	3,792,260
Fertilizers	22	5,767,280	5,227,340	2,126,820	346,540	2,362,250	15,830,230
Fuel oils	18	6,179,940	2,634,650	1,426,560	1,788,510	2,952,530	14,982,190
Furniture	39	1,783,130	675,340	295,620	211,300	575,020	3,540,410
Gasoline	17	28,527,740	12,698,330	6,171,290	8,835,880	13,292,940	69,526,180
Gravel	12	50,103,020	66,089,880	26,538,180	17,804,430	30,245,390	190,780,900
Live animals/fish	1	4,413,150	1,631,880	338,170	698,610	1,713,320	8,795,130
Logs	25	159,410	9,492,570	1,609,940	34,450	3,892,760	15,189,130
Machinery	34	6,399,960	1,130,240	1,128,320	1,281,840	3,893,690	13,834,050
Meat/seafood	5	1,891,740	2,529,490	885,560	269,980	915,940	6,492,710
Metallic ores	14	60,680	9,490	10,020	10,810	37,650	128,650
Milled grain prods.	6	3,827,420	1,576,820	673,850	333,300	1,317,000	7,728,390
Misc. mfg. prods.	40	2,987,230	988,460	449,920	164,140	856,670	5,446,420
Mixed freight	42	13,281,390	4,846,500	2,113,500	1,754,660	3,698,940	25,694,990
Motorized vehicles	36	4,862,040	664,880	319,140	348,700	958,710	7,153,470
Natural sands	11	11,410,030	13,427,640	5,591,850	3,573,950	6,302,790	40,306,260
Newsprint/paper	27	1,031,680	1,220,060	567,370	231,160	239,910	3,290,180
Nonmetal min. prods.	31	63,007,080	14,886,570	13,063,910	15,349,920	23,881,750	130,189,230
Nonmetallic minerals	13	2,074,480	1,708,220	389,710	430,810	1,244,200	5,847,420
Other ag prods.	3	10,342,760	9,885,480	3,101,610	2,414,550	4,848,240	30,592,640
Other foodstuffs	7	16,498,460	6,465,300	2,932,910	1,288,670	5,962,330	33,147,670
Paper articles	28	2,097,180	1,342,260	654,520	309,020	848,920	5,251,900
Pharmaceuticals	21	195,800	127,400	16,130	17,840	81,290	438,460
Plastics/rubber	24	1,186,870	1,167,130	492,120	18,770	455,910	3,320,800
Precision instruments	38	785,390	99,310	39,650	36,360	141,500	1,102,210
Printed prods.	29	1,889,270	721,350	345,290	242,610	913,060	4,111,580
Textiles/leather	30	908,560	335,630	204,140	59,390	406,410	1,914,130
Tobacco prods.	9	82,360	19,900	8,130	5,890	21,190	137,470
Transport equip.	37	1,060,550	164,560	173,150	186,352	651,632	2,236,244
Unknown	43	17,735,060	2,852,900	2,658,420	2,900,660	10,449,040	36,596,080
Waste/scrap	41	55,709,820	22,666,280	6,111,340	8,300,870	19,028,070	111,816,380
Wood prods.	26	6,859,330	3,617,180	1,880,970	591,340	3,050,210	15,999,030
		386,420,060	230,687,700	97,335,860	83,952,822	172,600,902	970,997,344

Note: The PECAS model does not deal with the following FAF STCG commodities:

- Gravel (12)
- Coal (15)
- Mixed Freight (42)
- Unknown (43)

The average tons per truck factors in Table 3 can be used, along with the 300 weekdays per year factor, to convert FAF annual truck ton flows to truck flows per day, by commodity. These flows can be grouped into PECAS commodity categories, for comparison with the PECAS output. Table 8 compares FAF observed daily truck flows with PECAS model flows.

Table 8: Comparison FAF Daily Truck Flows with PECAS Year 2000 Truck Flows

PECAS Commodity	FAF Observed Daily Flow	PECAS Year 2000 Daily Flow	% Difference (PECAS-FAF) / FAF
Agriculture Animals Output	3,200	3,220	0.6%
Agriculture Plants Output	9,040	9,270	2.5%
Agriculture Forestry and Fishing Output	700	710	1.4%
Mining and Extraction Output	10,730	10,760	0.3%
Manufacturing Food Output	18,380	18,520	0.8%
Manufacturing Textiles Output	620	600	-3.2%
Manufacturing Wood Products Printing Furniture Misc Output	8,900	8,830	-0.8%
Manufacturing Petro Paper Chemicals Plastic Rubber Glass Cement Output	39,250	40,010	1.9%
Manufacturing Metal Steel Machinery Output	10,950	11,040	0.8%

Fuels	19,920	19,980	0.3%
Scrap	23,890	24,360	2.0%
ALL COMMODITIES	**145,580**	**147,300**	**1.2%**

Note: The daily truck totals in Table 8 include trips for all trip lengths (both <50 miles and >50 miles).

The 2002 Commodity Flow Survey (undertaken through a partnership between the U.S. Census Bureau, U.S. Department of Commerce, and the Bureau of Transportation Statistics) gives data on the distance travelled by each commodity type, for shipments originating in California, by distance bands. This data has been used to obtain average "observed" trip lengths for the PECAS commodity categories, considering shipments made up to 750 miles in length. In turn, The California PECAS AA model buying and selling dispersion parameters have been adjusted, so that the PECAS model output gives average truck trip lengths by commodity that match these "observed" trip lengths.

Table 9 summarizes the modeled and observed trip lengths.

Table 9: Comparison 2000 CFS and PECAS Year 2000 average Trip Length

PECAS Commodity	2002 CFS Average Trip Length (Miles)	PECAS 2000 Average Trip Length (Miles)
Agriculture Animals Output	109	109
Agriculture Plants Output	100	100
Agriculture Forestry and Fishing Output	96	96
Mining and Extraction Output	26	26
Manufacturing Food Output	113	113
Manufacturing Textiles Output	207	207
Manufacturing Wood Products Printing Furniture Misc Output	141	141
Manufacturing Petro Paper Chemicals Plastic Rubber Glass Cement Output	84	84
Manufacturing Metal Steel Machinery Output	141	141
Fuels	50	50
Scrap	20	20

5. Application of the Long Distance Commercial Vehicle Model in CSTDM09

The long distance commercial vehicle trip tables obtained from factoring the California PECAS model for the year 2000, for Origin-Destination pairs >50 miles apart, are used directly in the year 2000 California travel model scenario.

For the year 2008 travel model scenario, the calibrated California PECAS AA model has been run with 2008 inputs derived from 2008 TAZ population and employment data inputs, to give a year 2008 truck trip table.

For all future year travel model scenarios, the year 2008 long distance truck tables are scaled using appropriate factors. The origin scaling factors can be derived from the relative changes in the primary and manufacturing employment numbers for each TAZ, as these employment categories "generate" the great majority of the production activities.